THE PIRACY OF THE YELLOWSTONE

EVER since the Grand Canyon of the Yellowstone was introduced to the general public, it has enjoyed a well-deserved fame for its grandeur and for the unrivaled beauty of its coloring. To the physiographer it has stood as a type preëminent of a very young river valley in the trench stage of development. All who have seen it have been profoundly impressed by it, and by many it is considered the most satisfying object of beauty in the region. It is now possible to introduce this already famous canyon in a new light, as the scene of one of the greatest acts of piracy on record.

The Yellowstone Lake, with an altitude of 7741 feet A. T., lies in a depression in the southeastern part of the great rhyolite plateau of the Yellowstone National Park. On the east of the lake the land rises rapidly to the high crests of the Absaroka range. On the north and west, and for the most part on the south, the land rises to the general level of the plateau, eight hundred to a thousand feet above the lake. North and south of the lake, and fringing the west shore, are considerable areas of flat land, not far above the present lake level and plainly lacustrine in origin.

The long southeast arm of the lake is seen to be the lower end of a magnificent mountain valley, here submerged. Beyond the lake the valley extends over thirty miles to the southeast, past the limits of the Park, up into the heart of the Absarokas. The upper Yellowstone River occupies this broad vale, at present wandering on a gradient which compels it to constant deposition, the flat bottom of aggraded material averaging over a mile in width for twenty miles southeast of the lake. This valley is manifestly very old, and it has its counterpart in the Lamar Valley in the northeastern part of the Park. It has been shown[1]

[1] ARNOLD HAGUE: The Age of the Igneous Rocks of the Yellowstone National Park, Am. Jour. Sci., 1896, I, p. 454.

that both these valleys were old and well developed before the rhyolites were poured out to form the Park plateau in Pliocene time. The lower courses of both these valleys are masked by the rhyolite flows, and the lake depression itself may be suspected to be a great mountain valley obstructed by lava flows.

The divide west of the lake lies on the flat-topped rhyolite plateau, and at various places there are cols of significant shape and altitude. Plainly some of them have been lines of drainage, showing that at some time water has flowed across the divide, making well-defined valleys. The stage road from the Upper Geyser Basin to the "Thumb," as the west arm of the lake is locally called, passes through one of these notches at the continental divide east of de Lacy Creek. It is rather a narrow valley, with walls perhaps a hundred feet high, cut right across the crest of the divide, yet flat-bottomed and at present marshy and undrained.

It is believed that this whole region has been covered with ice moving west from the Absarokas and north from the Tetons, and it may easily be supposed that in the unequal recession of the ice margin, obstructed drainage would give rise to overflow to the west, establishing channels that would be abandoned on a further recession of the ice. But there is one such channel which gives evidence of very long use even after the ice had left the plateau. This is a "windgap" between Overlook and Channel mountains at *D* in the map, page 263. Here a canyon with walls several hundred feet high cuts across the present divide, down almost to the contour of 7900 feet. Yet this surprising notch is poorly drained, puny streams starting from the marshy col and flowing to opposite oceans. The eastern one is an unnamed branch of Grouse Creek, the one to the west, called Outlet Creek, leads into the Heart Lake basin and so south to the Snake River. This notch has been recognized as a former outlet of the lake, and the fact is well known that the lake was once at this altitude, about one hundred and sixty feet above its present level. Lacustrine deposits are recorded on the United

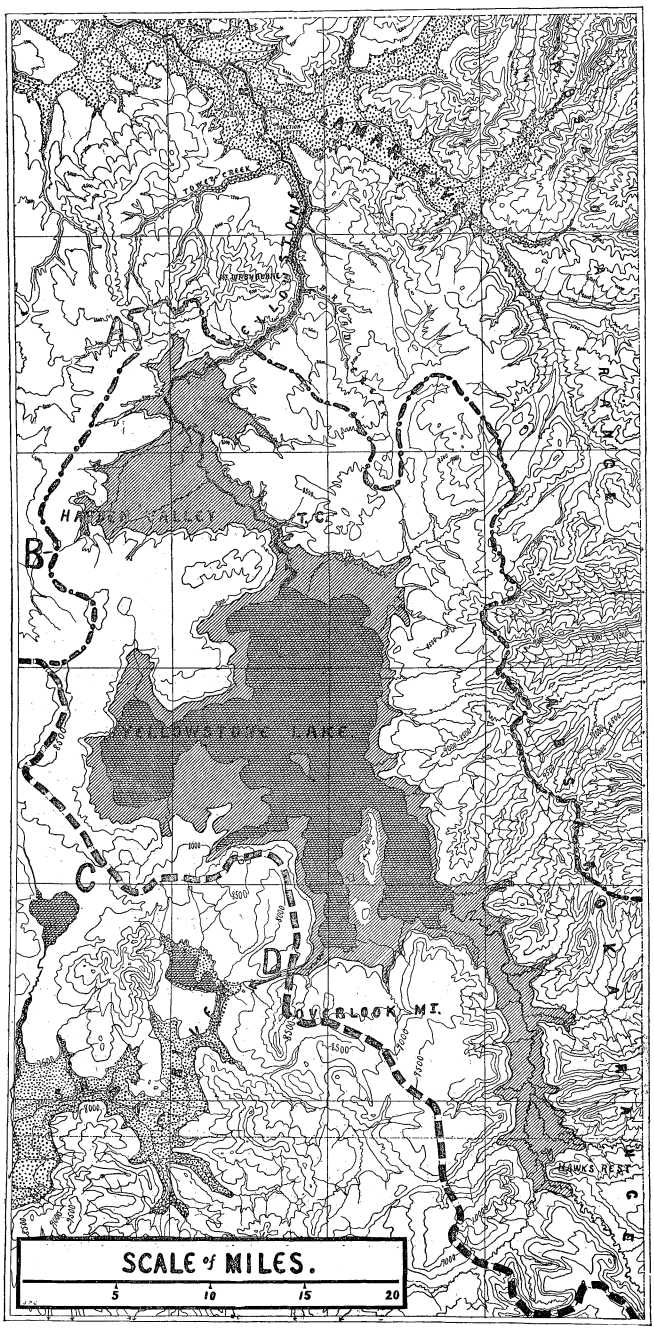

FIG. 1. Map of the eastern part of the Yellowstone National Park. The heavy dotted line *C D* is the present continental divide, the lighter line *B A* the ancient divide. The heavy hachured areas are present lakes, light hachured area is the ancient lake.

States Geological Survey maps,[1] practically up to the 7900-foot contour, all round the lake, and at its foot, to a point four miles below the present lake outlet, at Thistle Creek Canyon, marked *T. C.* on the map, p. 263. At this level also are found terraces, old sea cliffs and beaches, and while other shore phenomena are found at lower levels, as, for example, at the sixty-foot level, yet in some respects the most strongly marked records are at the higher level.

Through the Thistle Creek narrows to the north, the country flattens down into the Hayden Valley — a triangular depression in the plateau, ten miles east and west by seven or eight miles north and south. The surface of this depression is covered largely with moraine deposits of glacial drift, and all round this valley, particularly in the drift, the hills show a significant profile, which, immediately below the Thistle Creek Canyon, is undoubtedly terrace and sea cliff. On the upper courses of Trout Creek, and across the river, east of Crater Hills, similar profiles are seen. The central portion of Hayden Valley is a very flat plain, extending along the two streams, Alum and Trout Creeks. These two streams are wandering on a very low gradient, Trout Creek showing as beautiful an example of oxbows on a small scale as may be found anywhere, and in its wandering, its valley walls show stratified clays, the fresh-cut bank in one place near the roadway standing at a height of over thirty feet against the stream (Fig. 2, *A*, *B*).

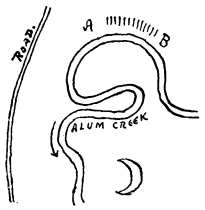

FIG. 2.

At the Grand Canyon the strongest impression one gets is that the canyon is extremely young, that the river is still actively corrading at bottom, and the walls all along are actively sloughing, by every process of degradation. Yet this impression of youth has its greatest emphasis, only when seen from the east flank of Mt. Washburne. Here, at an elevation of about two thousand feet above the plateau, the whole eighteen miles of canyon is in view, from the Falls to Junction Butte, dwarfed now

[1] Yellowstone National Park Folio, U. S. Geol. Surv., Washington, 1896.

by distance into a simple roadside ditch. With this view, it is easy to see that the canyon is not all the same age. The north half of it is distinctly older than the south or upper half. In the north half the shoulders are markedly rounded, the walls less steep, the stream at bottom has long ago found an axial equilibrium with the material it has to handle, and is not deepening or widening its bed in any striking way. It is a surprise to notice, too, that Broad Creek, which empties into the Yellowstone River just at the east foot of Mt. Washburne, has a canyon every whit as wide, as deep, and with shoulders as rounded as has the main canyon at this point.

One cannot help wondering why the Yellowstone Canyon is so young only above this point; why the deep stratified clays in Hayden Valley; why the terrace and cliffs at the high level in Hayden Valley. Why did the Yellowstone Lake abandon a good outlet at Overlook Mountain, and flow off to the north? The explanation may be read from the correlation of the available data as follows.

The Yellowstone Canyon for five miles or so below the falls is extremely young, the occupation by the river representing only a fraction of postglacial time. On the recession of the ice from the region, the plateau of rhyolite stretched untouched by the river action, from the south base of Mt. Washburne southeast across the site of the present canyon, at the general plateau level of about eight thousand feet. There was no canyon, and no Yellowstone River there. The two depressions in the plateau, Hayden Valley, and the present lake basin, if they existed in preglacial time, outflowed by some other route, at present unknown. On the recession of the ice from the region, these basins overflowed to the west, over available cols. Possibilities of such drainage lines, besides the one mentioned on the road to the "Thumb," may be suspected at *A*, *B*, *C*, and *D*, on the map, Fig. 1. But the one which established itself for greatest permanence was the one described at Overlook Mountain.

Now taking the topographic map and supplying a shore line for a lake outflowing at this channel, the surprising fact is shown

that such a lake not only pushes itself into the great valley over sixteen miles to the southeast, but it goes on thru the narrows at Thistle Creek, on the very level of the terrace and sea cliff noted. It covers all the Hayden Valley, with the exception of the very peaks of Crater Hills, and extends on past the falls and the Canyon Hotel to Inspiration Point, thus making a great twin lake extending over fifty-one miles from Inspiration Point on the north to Hawk's Rest far down into the Absarokas on the southeast. This greater lake is shown in the map by the lighter shaded area. The darker shading showing the area of the present lake.

The only assumption necessary in this reconstruction, is the absence of any considerable crustal deformation in postglacial time, and so far as known there is no evidence of any appreciable change of this kind in the area during this time.

Let us look now at the character of the Grand Canyon as it appears among its neighbors. The dominant topographic feature of the northeast part of the park is the great Lamar Valley. It is over two thousand feet deep, and its walls have receded under the tooth of time until a broad and generous vale a mile and more in width at bottom extends for twenty-five miles above the point of its confluence with the Yellowstone River. This vale was old in the Pliocene. It was deep and of generous size before the rhyolites and basalts were poured out to mask the old drainage and make the plateau in which the Yellowstone Lake and Canyon now lie. Once see this great valley and the impression is inevitable that the Yellowstone Canyon is a very late comer. Moreover, as a canyon it is not of much more importance than its neighbor of Tower Creek on the west. In short, the Yellowstone Canyon, from Junction Butte back to the east flank of Mt. Washburne, is not the work of the Yellowstone River at all, but was made by Broad Creek, then a small tributary of the Lamar, of no more consequence than Tower Creek, which joined it from the west. Its canyon may have been begun in preglacial time, but long after the general ice-sheet had left the region it remained an obscure stream, slowly

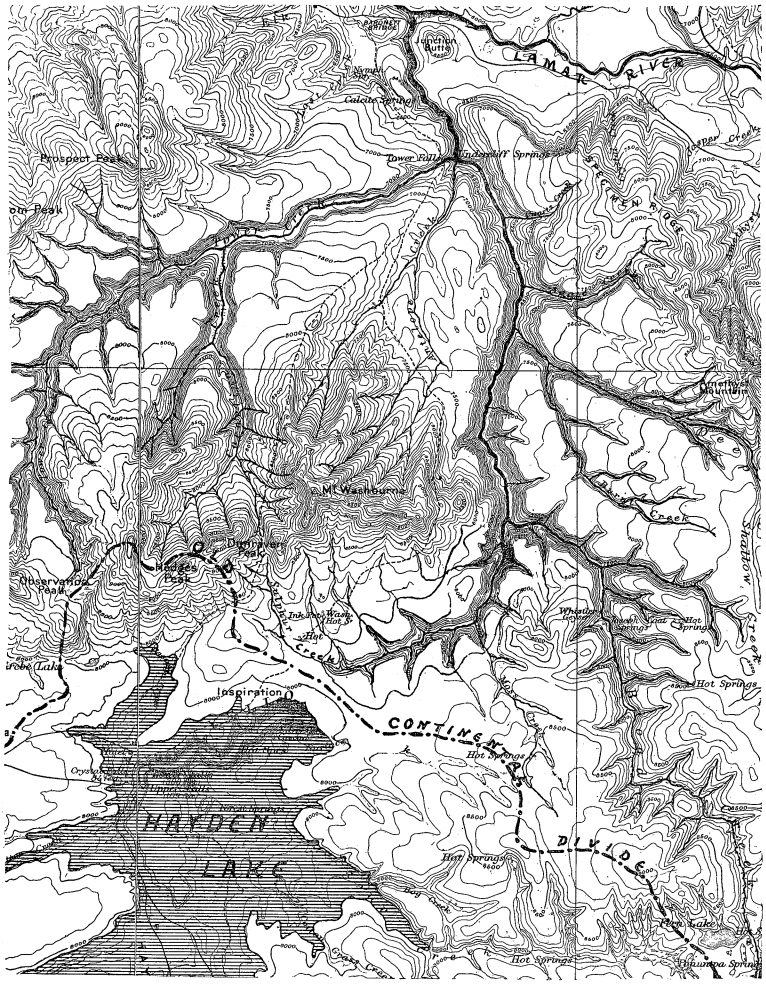

FIG. 3. Map of the scene of the piracy, showing relative size of the canyons of Tower Creek and Broad Creek. The contours of Broad Creek Canyon are supplied in place of the upper half of the present Yellowstone Canyon.

pushing its growing gorge back into the rhyolite of the plateau.

In Fig. 3 the site of the future Grand Canyon is represented, the contours being copied from the U. S. Geological Survey topographic map, with the exception that south from the mouth of the present Broad Creek the contours of Broad Creek itself are supplied, in the line of drainage of Sulfur Creek. The col between the Sulfur Creek gorge and the greater lake lay about two miles north of Inspiration Point in the old Continental divide. Yet the Sulfur Creek pirate was a long time eating thru this two miles or so of barrier. And all this while—a good fraction of postglacial time—the great lake was giving its water thru the Overlook Mountain channel to the Snake River, and the beaches, terraces, and sea cliffs were building at the contour of 7900 feet—about 160 feet above the present lake level. In the Hayden Valley part of the lake, similar beach records were making, and the stratified clays were being deposited off-shore.

The rate of advance thru the col by the Sulfur Creek pirate would depend upon three factors, the volume and gradient of the stream, and the nature of the rhyolite. The volume of water was not large, being only the drainage from the south flank of Mt. Washburne and the east flank of Dunraven Peak. The gradient was high, about 1500 feet, in the Sulfur Creek branch alone, while the rhyolite in the path of the canyon was in admirable condition for easy working.

The rhyolite, on first cooling from its flow, was hard and firm of texture, the obsidian or volcanic glass being one phase of it, usually found at the surface. In deeper levels it may have been as hard and crystalline as basalt; but the hot vapors from below have attacked the firm rock and in many places totally changed its character, making the felspars over into kaolin and leaving the once firm lava a crumbling mass, almost like slaked lime. Yet this solfataric action has not been universal. It has worked very effectively in certain areas, while in other places the solid rhyolite has wholly escaped the decomposing action. Were this not so, the canyon would long ago have advanced clear to the present lake.

The trend of physiographic history in the region was suddenly changed when the col was cut thru by the advancing canyon. The water of the lake began to flow out to the north, the increased volume very greatly hastening the deepening and widening of the trench. The lake level was rapidly lowered, the Overlook Mountain outlet was suddenly abandoned, and with this change the continental divide was transferred to its present position south of the lake. The lowering of the lake level was extremely rapid for a hundred feet, while the outlet was cutting in the decomposed rhyolite merely. In the hundred feet of rapid lowering but slight traces of shore action on the lake could be expected. But this rapid lowering was checked when the river reached the 7800-foot contour, for it came upon a wall of firm, undecomposed rhyolite standing squarely across its path — the site of the present Great Falls — and the river settled down to the task of sawing this barrier in two. It is still at the task, with nearly a quarter of its work yet to do. This barrier is only about a hundred feet thick, and is very plainly marked in the brow of the canyon wall, forming a narrow gateway thru which the water rushes. The inner walls of this gateway are very precipitous, as may be seen in the familiar view of the Great Falls. Immediately above and below this gateway the canyon walls fall away to a wide V-shape in section. The plan, Fig. 4, shows the relation of the barrier to this fall, and how the canyon is narrowed to the precipitous gateway in the barrier. As seen from the down-stream side, this barrier is evidently cut down a little over half its height, and one may easily conjecture that this fall, which is now 312 feet high, must have earlier been much higher, perhaps even 700 feet. The present brow of the fall is near the up-stream face of the barrier, and standing at the brow one may see that the firm rock of the barrier projects at the bottom on the east side of the stream, as a

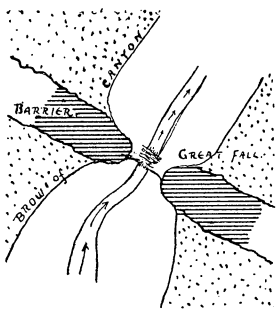

FIG. 4.—Diagram of the barrier at the great fall.

shelving ledge upon which the water is ceaselessly pounding, as shown in longitudinal section in Fig. 5. So this fall may be said to be showing signs of old age—that is, the rapids phase of development has already begun.

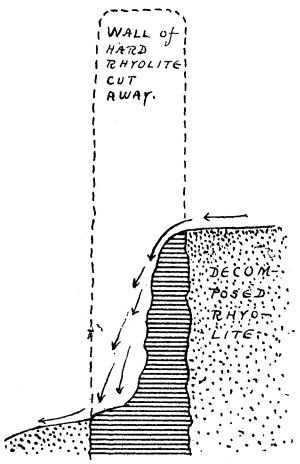

FIG. 5.—Longitudinal diagrammatic section of the great fall.

With the lake outlet approaching this barrier at the contour of 7800 feet a current was formed at the Thistle Creek narrows, and two separate lakes resulted, with a short river between. The lower lake, covering Hayden Valley we may provisionally call Hayden Lake. The river at the narrows had glacial drift only to work on and was competent to cut this out widely as Hayden Lake level followed the lowering brow of the falls.

The problem was made more complex when the river discovered another wall of firm rhyolite at the site of the Upper Fall. This wall is much thicker than the lower one, and the process of cutting is proportionally slower. It was the lowering of this barrier which determined the lowering of Hayden Lake level. When the wall was cut somewhat below the 7700-foot contour, Hayden Lake was drained, and this has only very recently been accomplished, as is shown by the flat and sinuous course of Trout Creek.

The wearing down of the barrier at the Upper Fall has always lagged behind that of the lower. It could not be touched at all, until the lower barrier was reduced below its level, and the height of the Upper Fall has always been limited at its lower level, by the brow of the Lower Fall. The Upper Fall has increased in height almost uniformly with the decrease in height of the Lower Fall, and it is plain to be seen, that when the Lower Fall has finally sawed thru its barrier, the river will carry the canyon gradient back to the Upper Fall which will then be perhaps four hundred feet high.

With the lowering of these two barriers, other barriers were uncovered in the path of the stream above. The most important of these is a ridge of firm rhyolite in the bottom of the Thistle Creek narrows. This became a large factor in the history of the Yellowstone Lake, when in the cutting of the canyon at this point, this firm rhyolite was reached, at a level about sixty feet above the present lake. The lake level since then has waited on the lowering of this one barrier. It is the only barrier which now determines the lake level, altho it seems plausible that in earlier stages, a barrier at Mud Geyser, and perhaps even the Upper Fall barrier, were agents also in maintaining the lake at the sixty-foot terrace, the action on each barrier being much deferred by the lack of gradient due to the former higher elevation of these lower barriers.

This is the postglacial history of Yellowstone Lake and Canyon as it may be read from the data in hand. The whole great lake, with its drainage basin of about fifteen hundred square miles, was captured by the little Sulfur Creek canyon, taken bodily from the Snake River and the Pacific slope, and added to the Lamar River and the Atlantic slope. And the volume of water in the captive stream was so great as to dominate the lower valley of the Lamar, and reduce that older stream to the rank of a minor tributary.

JOHN PAUL GOODE.

UNIVERSITY OF CHICAGO.